APPENDIX G-GS1
GEOLOGY, SOILS, AND PALEONTOLOGICAL RESOURCES

This appendix provides a summary of the results of the following detailed geologic study plan reports prepared for the Oroville Facilities relicensing: SP-G1, *Effects of Project Operations on Geomorphic Processes Upstream of Oroville Dam*; and SP-G2, *Effects of Project Operations on Geomorphic Processes Downstream of Oroville Dam*. The study plan reports provide a basis for the definition of the affected environment as described in Section 5.3.1 of the Preliminary Draft Environmental Assessment (PDEA). The completed study plan reports are provided in their entirety in an informational supplement and are also available on the Oroville Facilities website at http://orovillerelicensing.water.ca.gov/wg_plans_envir.html.

This appendix also describes the processes and bases used to evaluate the No-Action Alternative, the Proposed Action, and Alternative 2 and their potential effects on geologic resources. Implementation of any of the alternatives is anticipated to produce two distinct types of effects: (1) direct effects related to construction activities or changes in Oroville Facilities operations; and (2) indirect effects related to changes in hydrologic conditions. The potential effects related to changes in hydrologic conditions may affect environmental resources beyond the project study area and are addressed under the cumulative analysis (see Section 5.7.4, Cumulative Effects).

G-GS1.1 FLUVIAL-12, METHODOLOGY

Modeling results from a 50-year FLUVIAL-12 model run predict the sediment yield for the next 50 years in the lower Feather River with the assumption that the sediment inflow into the study reach is cut off by Oroville Dam. The amount of bed material load in the Feather River passing the Thermalito Afterbay Outlet (in the Low Flow Channel reach) was modeled at 0.3 million tons, or about 6,000 tons per year, or 16 tons per day. This is about 3 percent of the pre-dam bedload of 485 tons per day estimated by the U.S. Geological Survey (USGS). The yield is primarily a result of channel erosion because Oroville Dam traps nearly all of the incoming bed material. Finer sediments are more easily removed from the channel boundary, leaving the coarser sediment behind. The selective sediment transport has resulted in the gradual coarsening and armoring of the bed material. The modeling also showed that much of the sediment delivered from the channel above River Mile 61 is trapped in gravel mining pits excavated immediately adjacent, and connected to the river channel.

The modeled pattern of sediment delivery shows a sharp rise in delivery in the High Flow Channel reach just below the Thermalito Afterbay Outlet. This is likely related to the increase in flow just below the Thermalito Afterbay and therefore an increase in erosion from the channel boundary. The total yield of the Low Flow and High Flow Channels is 2.9 million tons for 50 years.

The model run shows a large increase in the sediment size after 50 years. The largest increase in size was directly below the Fish Barrier Dam, showing a D50 increase from

120 millimeters (mm) to 150 mm, and at River Mile 56, showing an increase from 60 mm to 110 mm.

The modeled channel geometry changed because of scour and fill, which is not generally distributed uniformly across the channel width. Furthermore, scour of the bed may be accompanied by scour or fill in the overbank area, or vice versa. These changes in channel morphology in turn directly affect the hydraulics of flow and sediment transport.

Changes in channel geometry are depicted in the model by changes in thalweg profile and changes in channel cross section. Modeled water surface and channel thalweg profiles show that channel bed degradation is predicted at most cross sections, with aggradation at some locations. Cross section measurements showed average post-dam thalweg decreases of 1 to 5 feet in the Low Flow Channel, 1 to 4 feet between the Thermalito Afterbay Outlet and the Gridley Bridge, and 2 to 5 feet from Gridley Bridge to Honcut Creek. Channel degradation is consistent with the continued erosion. Future changes are limited by bed armoring, which in turn will reduce future bed erosion and sediment yield.

Those reaches near mining areas are subject to greater changes than other areas. This is because of the disruption in channel profile and cross section, resulting in sediment deposition within the mining areas and scour in the areas immediately above and below.

G-GS1.2 EFFECTS OF THE NO-ACTION ALTERNATIVE

This section provides quantitative and qualitative analyses of potential effects on geologic, soils, and paleontological resources with implementation of the No-Action Alternative, relative to existing conditions. Because no potential effects were identified for paleontological resources, there is no further discussion regarding this topic. Although the following topical outline is consistent for analysis of all alternatives, effects in several issue areas are not anticipated to occur under the No-Action Alternative. From a geologic/soils resources perspective, there are only a few differences between existing conditions and the No-Action Alternative. (See Section 3.1, No-Action Alternative, for a detailed description of the No-Action Alternative.)

Quantitative and qualitative analyses were performed using the methodology described in FLUVIAL-12, Methodology. This analysis predicts sediment yield, sediment delivery patterns, and changes to channel geometry over the next 50 years. Although future operations of the Oroville Facilities are expected to differ from existing conditions, the effects of the No-Action Alternative on geology and soils resources—gravel recruitment (sediment transport), woody debris recruitment, and channel complexity—are not expected to differ from those that would occur under existing conditions.

G-GS1.2.1 Geologic/Soils Components Affected by the Oroville Facilities

Currently, more than 97 percent of the sediment from the upstream watershed is trapped in the upstream reservoirs, including Lake Oroville, resulting in sediment

deprivation downstream. Virtually the entire gravel component of the former sediment load has been eliminated from the river downstream of the various Oroville Facilities. Currently, only very fine sediment is discharged from Lake Oroville to the stream below.

G-GS1.2.1.1 Sediment Transport/Gravel Recruitment

Under the No-Action Alternative, Oroville Dam, the Thermalito Diversion Dam, and the Fish Barrier Dam would continue to block significant transport of all sediment sizes from the upper Feather River to the lower Feather River that is not initially blocked by the upper watershed reservoirs. High Oroville Facilities releases, such as those implemented for flood management purposes, would mobilize existing sediments within the lower Feather River, particularly the smaller substrate particle sizes. Removal of these smaller substrate sizes, which would not be replaced by upstream sediment/gravel contributions, would result in a gradual relative coarsening of the particle size distribution of the substrate in the upper portions of the lower Feather River. Currently, the highest proportion of coarse substrate components is present in the upstream-most portion of the lower Feather River, that reach below the Fish Barrier Dam but above the Thermalito Afterbay Outlet. Under the No-Action Alternative, this reach would likely become more armored over time. However, the 1983 Operating Agreement between DFG and DWR provides for an annual recommendation to DWR for mutual agreement on spawning gravel maintenance activities.

Continued deprivation of the sediment load in the lower Feather River would result in the continued reduction in the formation of sediment benches, which affects riparian vegetation colonization and succession. (See Section 5.6, Terrestrial Resources, for additional information on riparian vegetation.) Riparian vegetation provides overhanging cover for rearing fish, riparian shade, invertebrate contributions to the fish food base, and future large woody debris site contributions. Additionally, soft sediment substrates also contribute to the function of capture and retention of large woody debris. Therefore, under the No-Action Alternative, a continued lack of sediment recruitment to the lower Feather River would result in the incremental degradation of geomorphic processes, contributing to a decrease in the quality and diversity of habitat for aquatic resources in the lower Feather River.

G-GS1.2.1.2 Woody Debris Recruitment

Under the No-Action Alternative, the Oroville Facilities would continue to block the upstream contribution of large woody debris to the lower Feather River. The lowest proportion of large woody debris availability likely would continue to occur in the upstream-most reach of the lower Feather River, from the Fish Barrier Dam to the Thermalito Afterbay Outlet. Downstream of the Thermalito Afterbay Outlet, the river likely would continue to support a greater availability of large woody debris cover than the reach upstream of the outlet because opportunities for large woody debris recruitment likely would remain higher in the High Flow Channel. The continued lack of large woody debris recruitment to the lower Feather River would result in an incremental degradation of the quantity and quality of large woody debris present in the lower

Feather River and would reduce the quality and diversity of habitat for aquatic resources.

G-GS1.2.1.3 Channel Complexity

Under the No-Action Alternative, channel complexity would be reduced through continued riverbed incision and channel confinement. Continued operation of the Oroville Facilities with relatively static and moderated flow regimes in the Low Flow Channel under the No-Action Alternative likely would continue to limit the geomorphic processes that result in channel complexity, resulting in the ongoing incremental degradation of the quality and diversity of aquatic resource habitat relative to existing conditions.

G-GS1.3 EFFECTS OF THE PROPOSED ACTION

This section provides qualitative analyses of potential effects on geologic, soils, and paleontological resources with implementation of the Proposed Action, relative to the No-Action Alternative. Because no potential effects were identified for paleontological resources, there is no further discussion regarding this topic. From a geology and soils resources perspective, there are only a few differences between the No-Action Alternative and the Proposed Action. (See Section 3.1, No-Action Alternative, and Section 3.2, Proposed Action, for a detailed description of No-Action Alternative and Proposed Action conditions.) While future operations of the Oroville Facilities are expected to differ from existing conditions, the effects of the Proposed Action are anticipated to be essentially the same as under the No-Action Alternative. Therefore, no quantitative analysis is required or provided to show that potential effects on geology and soils resources—gravel recruitment (sediment transport), woody debris recruitment, and channel complexity—are not expected to differ from those that would occur under existing conditions.

Actions included in the Proposed Action that are relevant to the assessment of the effects on aquatic resources, and that are not included in the No-Action Alternative, consist of programs for gravel supplementation and improvement, large woody debris supplementation and improvement, and side channel enhancements. The actions included in the Proposed Action are evaluated qualitatively in the subsections below. A detailed description of the methodology used to analyze potential effects on geology and soils resources is provided in SP-G2, *Effects of Project Operations on Geomorphic Processes Downstream of Oroville Dam*.

G-GS1.3.1 Geologic/Soils Components Affected by the Oroville Facilities

G-GS1.3.1.1 Sediment Transport/Gravel Recruitment

The Proposed Action includes supplementing gravel in the lower Feather River directly below the Fish Barrier Dam and at selected riffles between the Fish Barrier Dam and Honcut Creek that are considered to have high potential for anadromous salmonid spawning. The Proposed Action also provides for the ripping and raking of the riverbed

substrate in selected areas of the lower Feather River that are potential salmonid spawning sites, but where the substrate has become armored.

Specific locations that may benefit from gravel supplementation were identified in SP-G2. Additional information would be needed to identify the appropriate volume and methodology for gravel placement (riffle supplementation, riffle creation, etc.). Surveys would also be needed after the gravels are introduced in the channel to determine their effectiveness to benefit spawning salmonids. Depending on the findings of surveys conducted after gravel supplementations, additional supplementations may be conducted in the same areas or certain sites may be abandoned. Likewise, potential sites that may benefit from ripping and raking were identified in SP-G2. In general, to avoid the potential for additional channel incision in the Low Flow Channel, the majority of the ripping and raking would be done in the lower portions of the Low Flow Channel near the Thermalito Afterbay Outlet. Future surveys may determine other areas where ripping and raking of substrate may enhance spawning habitat.

Information gathered from SP-G2 has identified specific sites downstream of the Fish Barrier Dam and upstream of the Thermalito Afterbay Outlet that may benefit from supplementation of spawning gravel. Supplementation of gravel at these locations is intended to increase suitable spawning habitat quality and quantity for anadromous salmonids by restoring habitat substrate that has become armored. (See Section 5.5, Aquatic Resources, for additional information on salmonid habitat.)

The spawning gravel supplementation and improvement program would provide the greatest benefit to the spawning areas in the upstream-most portions of the Low Flow Channel below the Fish Barrier Dam because they currently have the most degraded substrate quality and the least suitability for salmonid spawning. Additionally, gravel supplemented near the base of the Fish Barrier Dam would be mobilized during flood management events and would be redistributed downstream, mimicking normal gravel recruitment that occurred before dam construction. Subsequent gravel placement would be required after future peak-flow events to maintain benefits provided by supplementation of spawning gravel.

G-GS1.3.1.2 Woody Debris Recruitment

Implementation of the Proposed Action would include supplementing large woody debris in the lower Feather River, particularly in the Low Flow Channel below the Fish Barrier Dam, to satisfy fish habitat improvement goals for the duration of the license period. Large woody debris supplementation would:

- Contribute to both the geomorphic and ecological functions of the lower Feather River;
- Enhance rearing habitat for juvenile salmonids by providing cover;
- Create scour pools that may serve as holding habitat for anadromous salmonids;

- Trap and organize sediment, allowing recruitment of riparian vegetation, and decaying large woody debris; and

- Provide an additional source of instream nutrients for aquatic organisms.

Large woody debris placed at certain locations below the Thermalito Afterbay Outlet may also enhance habitat for warmwater species such as black bass.

The Proposed Action includes the placement of large woody debris in the lower Feather River primarily from the Fish Barrier Dam to the Thermalito Afterbay Outlet, and possibly in other locations downstream of the Thermalito Afterbay Outlet. The results of SP-G2 indicated that the lower Feather River below the Thermalito Afterbay Outlet has a fairly healthy abundance of large woody debris. In general, single logs, groups of logs, or combinations of logs and boulders or gravel would be placed in the river and anchored or cabled together (Flosi et al. 1998). Anchoring would probably be required for projects that are intended to be site specific, such as riprapped banks or side channels. Wood may also be anchored at banks with cables or between natural or artificial structures.

Under current regulated flow regimes, large woody debris placement would provide localized benefits on fish habitat. When a flood management flow event occurs, the magnitude of the event would redistribute both naturally recruited and supplemented large woody debris. While this redistribution is considered a normal ecosystem function, the large woody debris in the upstream reaches of the Low Flow Channel would need to be replaced following these events. In the event that large woody debris moves out of the Feather River during extreme flow events, it would provide fish habitat benefits downstream on the Sacramento River, perhaps as far as the Sacramento–San Joaquin Delta.

Placement of large woody debris could create conflicts with landowners adjacent to the channel if bank erosion were inadvertently increased as a result of flow diversion. Placement of large woody debris could also decrease river navigability in some areas.

G-GS1.3.1.3 Channel Complexity

Implementation of the Proposed Action includes enhancement of the existing side-channel habitat in Hatchery Ditch and Moe's Ditch, both downstream of the Fish Barrier Dam and adjacent to the Feather River Fish Hatchery. Enhancements to these existing side channels could include reforming the channel for increased water depth and channel complexity, placing boulders and woody debris for cover and velocity diversity, and gravel substrate supplementation. The enhancement of these existing side channels would primarily benefit steelhead and spring-run Chinook salmon by increasing the quantity and quality of spawning and rearing habitat.

G-GS1.4 EFFECTS OF ALTERNATIVE 2

This section provides qualitative analyses of potential effects on geologic, soils, and paleontological resources with implementation of Alternative 2, relative to the No-Action Alternative. Because no potential effects were identified for paleontological resources, there is no further discussion regarding this topic. Although the following topical outline is consistent for analysis of each alternative, effects on several issue areas are not anticipated to occur under Alternative 2. From a geology and soils resources perspective, there are only a few differences between the No-Action Alternative and Alternative 2. (See Section 3.1, No-Action Alternative, and Section 3.3, Alternative 2, for a detailed description of No-Action Alternative and Alternative 2 conditions.) Oroville Facilities operations under Alternative 2 are anticipated to be the same as under the No-Action Alternative. Therefore, no quantitative analysis is required or provided to show potential effects on geology and soils.

Actions included in Alternative 2 that are relevant to the qualitative assessment of the effects on geology and soils resources, and that are not included in the No-Action Alternative, consist of gravel and large woody debris supplementation and improvement programs in the lower Feather River and improvements to existing side-channel fish habitat and creation of new side-channel habitat. These actions are evaluated qualitatively in the subsections below. A detailed description of the methodology used to analyze potential effects on geology and soils resources is provided in SP-G2, *Effects of Project Operations on Geomorphic Processes Downstream of Oroville Dam*.

G-GS1.4.1 Geologic/Soils Components Affected by the Oroville Facilities

G-GS1.4.1.1 Sediment Transport/Gravel Recruitment

Actions associated with gravel supplementation and improvements under Alternative 2 are identical to those actions included with implementation of the Proposed Action. See Effects of the Proposed Action above for an evaluation of these actions relative to the No-Action Alternative.

G-GS1.4.1.2 Woody Debris Recruitment

Actions associated with large woody debris supplementation and improvements under Alternative 2 are identical to those actions included with implementation of the Proposed Action. See Effects of the Proposed Action above for an evaluation of these actions relative to the No-Action Alternative.

G-GS1.4.1.3 Channel Complexity

Implementation of Alternative 2 would include enhancement of the existing side-channel habitat in Hatchery Ditch and Moe's Ditch, both located adjacent to the Feather River Fish Hatchery, downstream of the Fish Barrier Dam. Alternative 2 would also include the creation of additional side channels in the Low Flow Channel. It is assumed that the flows required to maintain these additional side channels are provided for in the Alternative 2 flow increases, and discussed in Section 5.4.2.1.

Creation of new and enhancements of the existing side channels could be coordinated with the proposed supplementation of large woody debris and gravel, and include reforming and reshaping the channel for increased water depth and channel complexity. The creation of new and enhancement of these existing side channels would primarily benefit steelhead and spring-run Chinook salmon by increasing the quantity and quality of spawning and rearing habitat.

G-GS1.5 REFERENCES

Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 1998. California Salmonid Stream Habitat Restoration Manual, State of California, The Resources Agency, California Department of Fish and Game, Inland Fisheries Division, Sacramento, CA. Third Edition.